Environment Canada
Environmental Protection Service
Pacific Region
Yukon Branch

WATER QUALITY AND BIOLOGICAL SURVEY OF STOKES POINT AND KING POINT, YUKON - BEAUFORT SEA COAST

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by

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ABSTRACT

A baseline inventory of water chemistry, sediment and biological conditions was undertaken by the Environmental Protection Service on the Beaufort Sea coast of the Yukon in August 1982. Investigations were conducted in two areas of potential development at King Point and Stokes Point with samples being collected from lake, lagoon and nearshore marine habitats.

The nearshore marine stations were predominated by the Arctic water mass with localized mixing occurring. Sediment metal levels and oils and grease levels were found to be typical of other Beaufort Sea sediments. Twenty three species of benthic invertebrates were identified. Four species not previously recognized in other Beaufort Sea literature were identified in the Stokes Point nearshore marine samples.

The lagoons have brackish water characteristics reflecting recent closure and separation from marine water. King Point lagoon exhibits lower salinity and conductivity than Stokes Point lagoon. One station at Stokes Point Lagoon showed excessively high oils and grease levels.

Water chemistry data from the freshwater lake sample indicated low nitrite, nitrate levels.

Tissue samples were obtained from two fish species and one isopod species and analyzed for extractable metals.

RÉSUMÉ

Le Service de Protection de l'Environnement a procédé à une étude de base sur les caractéristiques physico-chimiques de l'eau, des sédiments et conditions biologiques de la mer de Beaufort sur la côte du Yukon en août 1982. Les investigations ont portées sur deux régions susceptibles d'être développées; King Point et Stokes Point. Des échantillons provenant de lacs, lagunes, et habitats marins ont été récoltés.

Les stations marines réflètent les caractéristiques des eaux arctiques bien que parfois l'on note l'influence des eaux douces dans la zone de brassage. Les quantités de métaux, huiles et graisses contenues dans les sédiments sont typiques des résultats obtenus des sédiments de la mer de Beaufort provenant de différentes études. Vingt-deux espèces d'intertébrés benthiques ont été idenfiées. Quatre nouvelles espèces, jamais rencontré dans les précédentes études de la mer de Beaufort, ont été identifiées dans les échantillons des stations marines près de Stokes Point.

Les lagunes contiennent des eaux saumâtres réfletant la récente fermeture du bras de mer. La lagune a King Point présente une salinité et conductivité plus faible que la lagune a Stokes Point. Une des stations de la lagune de Stokes Point indique un présence excessive d'huile et graisse.

Les données chimiques de l'eau des lacs indiquent un faible taux de nitrate et nitrite.

Les échantillons de tissus pour l'analyse des métaux extractables, furent obtenus de deux espèces de poisson et une espèce d'ispode.

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1 INTRODUCTION

Two areas on the Yukon's north coast have been proposed as potential locations for deep water port and associated land facilities by companies involved in Beaufort Sea hydrocarbon exploration and production. Stokes Point, favored by Gulf Canada Resources Incorporated, and King Point, favored by Dome Petroleum Limited, are located 225 km and 200 km, respectively, west of Tuktoyaktuk, Northwest Territories, the present centre of activity for hydrocarbon activities in the Beaufort Sea (Figure 1). Gulf Canada Resources have proposed a deep water port and shore based staging area to support deep water drilling platforms and as an overwintering maintenance facility during exploration and production phases. Dome Petroleum has identified King Point as a potential deep water port and land based facility for the production phase of hydrocarbon development in the area. The present use of the areas is largely by Inuit hunters from the Mackenzie Delta who establish temporary camps along the coast during whaling trips. Stokes Point has remnants of an abandoned DEW Line development, consisting of fuel tanks, a building and a landing strip.

Relatively little site specific information exists regarding water and sediment characteristics for these areas. There is also a scarcity of information on benthic invertebrates for the nearshore habitats in these specific locations and the area in general. The information that is available comes from reports done in the 1970's in support of the Arctic Gas proposal and more recently from the Environmental Impact Statement prepared by Dome, Esso and Gulf in support of Beaufort Sea activities.

The Environmental Protection Service (EPS) Yukon Branch in August 1982 undertook a baseline inventory study to obtain additional site specific data which could subsequently be used for proposed project review and impact assessments. Measurements of water quality (salinity, temperature, dissolved oxygen) and sediment characteristics

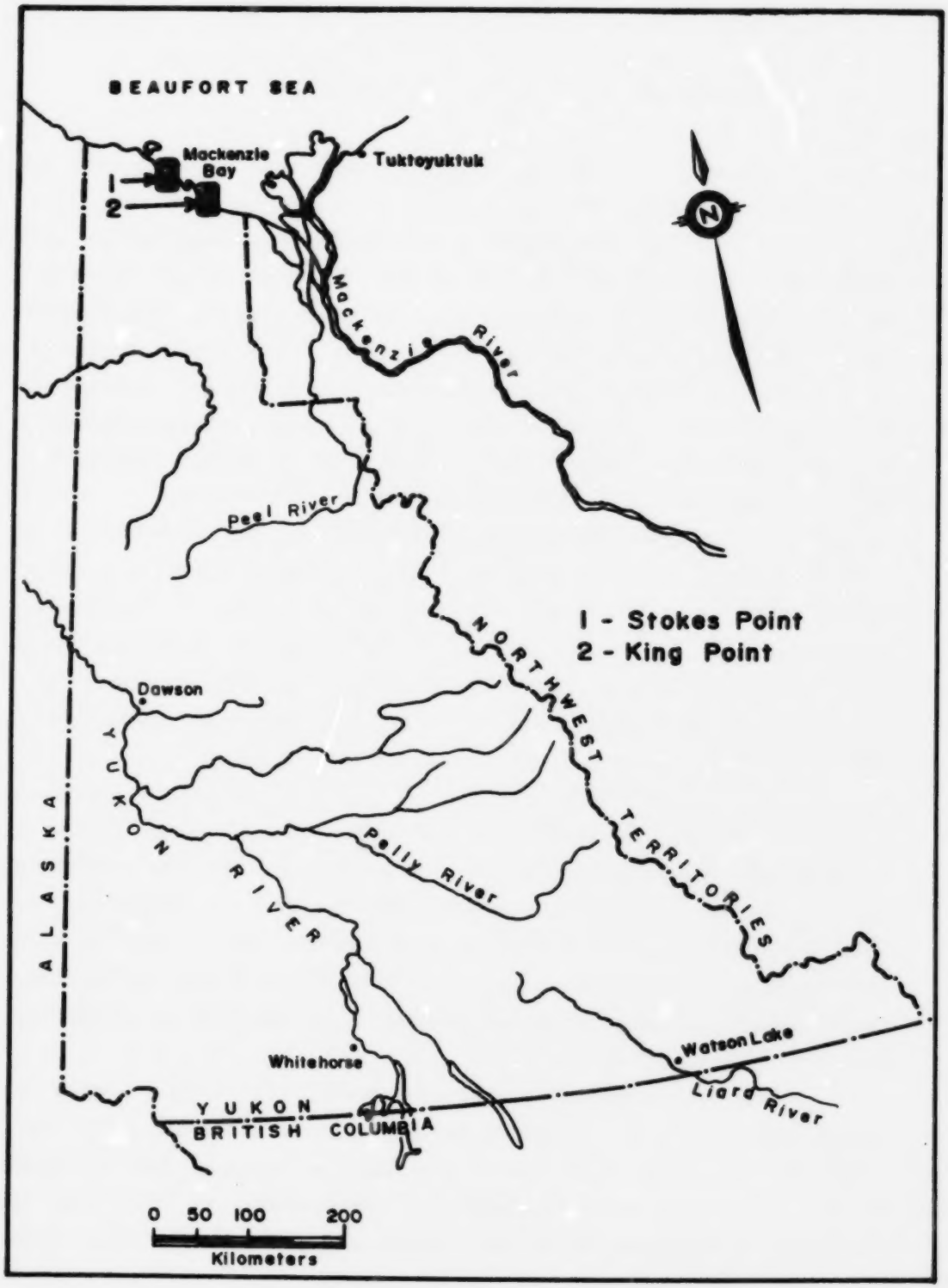

Figure 1 Location of Stokes Point and King Point study areas.

(particle size, heavy metals, oils and greases) were made. Species composition of benthic invertebrate communities in the nearshore marine, lagoon and freshwater lake habitats were determined by benthic grab samples.

2 STUDY AREAS

The study areas are located near Stokes Point (69°20'N, 138°43'W) and King Point (69°07'N, 137°57'W) along the Beaufort Sea coastline of the Yukon Territory (Figure 1).

Data was collected at eight sampling stations in each study area. The Stokes Point sampling included five stations in the nearshore marine zone, two in the brackish lagoon, and one in a freshwater lake (Figure 2). The sampling at King Point consisted of five stations in the nearshore marine zone and three in the brackish lagoon (Figure 3).

Aerial photographs of the Stokes Point and King Point areas are shown in Figures 4 and 5 respectively.

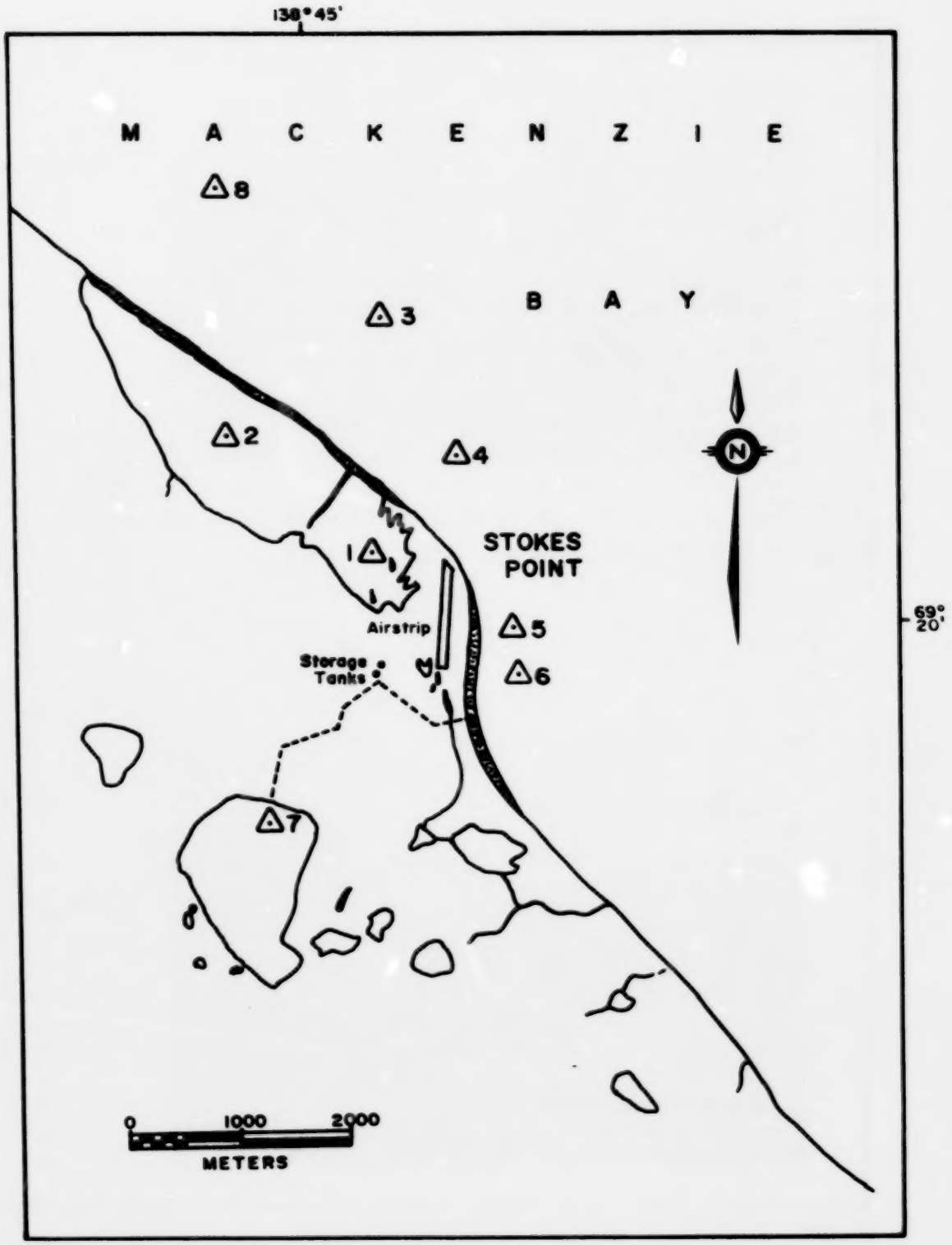

Figure 2 Location of sampling stations near Stokes Point.

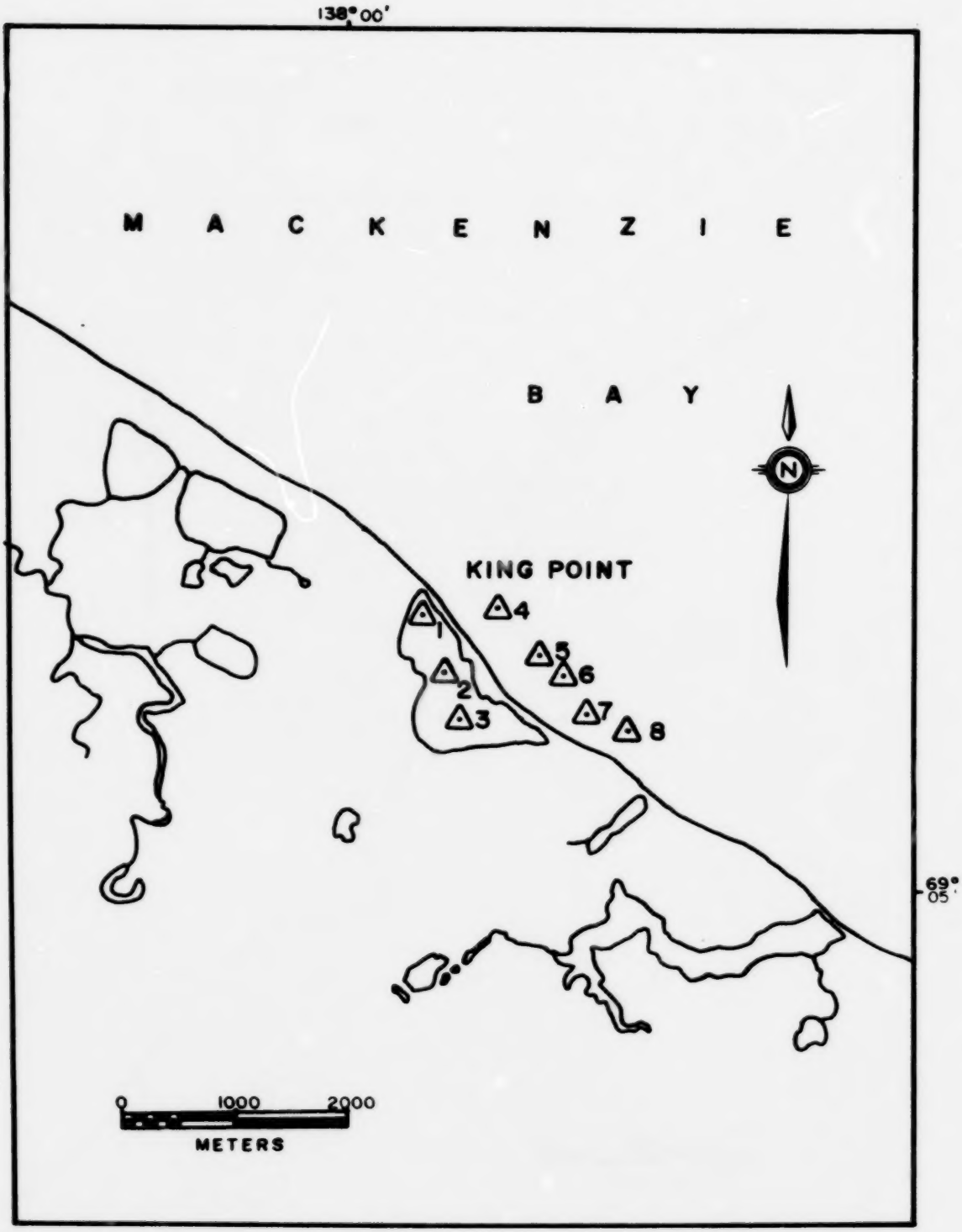

Figure 3 Location of sampling stations near King Point.

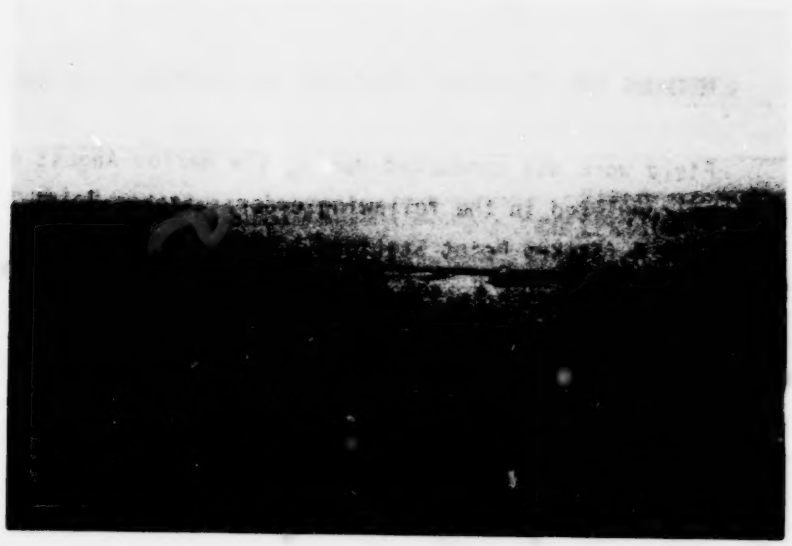

FIGURE 4 AERIAL PHOTOGRAPH OF THE STOKES POINT AREA. VIEW IS TO THE NORTH WITH THE EASTERN PORTION OF LAGOON IN FOREGROUND.

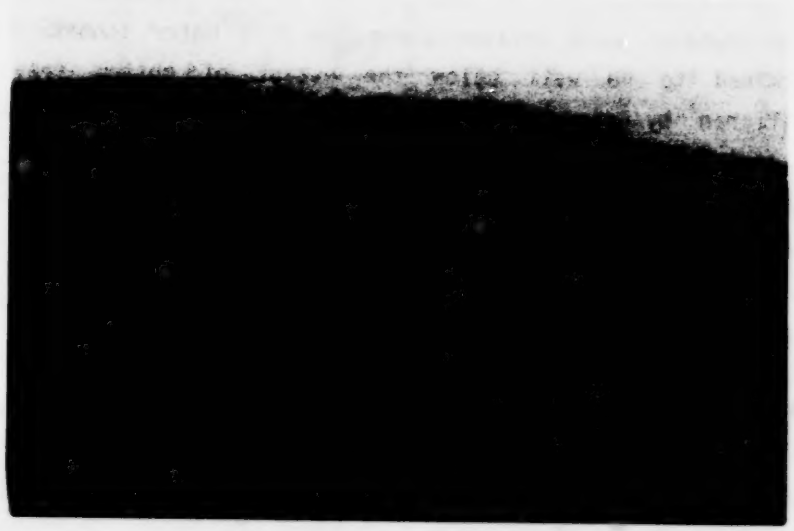

FIGURE 5 AERIAL PHOTOGRAPH OF THE KING POINT AREA. VIEW IS TO THE NORTH WITH LAGOON IN FOREGROUND.

3 METHODS

Field work was conducted during the period August 4-7, 1982. Sampling was completed in the following order: Stokes Point Stations 3 to 8 on August 4, Stokes Point Stations 1 and 2 on August 5, King Point Stations 4 to 8 on August 6, and King Point Stations 1 to 3 on August 7. Weather conditions during this period varied from cool and windy at Stokes Point and improved to be sunny and calm at King Point. Tides during the survey fluctuated between 0.13 and 0.92 meters above chart datum (F.E. Stephenson, 1983).

Each station was sampled once during the survey. Information on water quality was collected at two depths, surface and 0.5 m above bottom. Three sediment and five bottom fauna samples were attempted at each station. Sample collection and preservation procedures followed the methods described in Environment Canada (1976), Pollution Sampling Handbook.

A summary of the data collected and analyzed is shown in Table 1.

The marine stations were sampled from an inflatable boat, while an existing wharf was used to access the freshwater station. The marine stations were located along the five meter isobath (which was determined to be well below the extent of bottom freezing) and established by using a sounding line from the surface. An anchor was used to remain stationary while the data was systematically collected in the following order: water quality parameters, sediment samples, and bottom fauna.

The following sections provide a more detailed account of the methods employed.

3.1 Water Quality

The parameters measured in the field were temperature, pH (freshwater only), conductivity and salinity. The surface water temperature was recorded using a standard centigrade thermometer. The lower level temperature, as well as the salinity and conductivity, was measured using the YSI Model 33 conductivity meter.

TABLE 1 SUMMARY OF THE DATA COLLECTED AND ANALYZED

SAMPLING STATION	FIELD COLLECTION: In Situ Measurements	Water Samples	Sediment Samples	Invertebrate Samples	LABORATORY ANALYSIS: Water - Nutrients	Water - Metals	Sediment - Size	Sediment - Metals	Sediment - Oils	Invertebrates
STOKES POINT										
1	x	-	3	5	-	-	x	x	x	x
2	x	-	3	5	-	-	x	x	x	x
3	x	-	3	0	-	-	x	x	x	-
4	x	-	0	0	-	-	-	-	-	-
5	x	-	3	5	-	-	x	x	x	x
6	x	-	3	5	-	-	x	x	x	x
7	x	2	3	3	x	x	x	x	x	x
8	x	-	3	5	-	-	x	x	x	x
KING POINT										
1	x	-	3	5	-	-	x	x	x	x
2	x	-	3	5	-	-	x	x	x	x
3	x	-	3	5	-	-	x	x	x	x
4	x	-	2	0	-	-	x	x	x	-
5	x	-	0	0	-	-	-	-	-	-
6	x	-	3	3	-	-	x	x	x	x
7	x	-	3	5	-	-	x	x	x	x
8	x	-	3	5	-	-	x	x	x	-

x = samples and analysis completed.

Water samples were collected to determine dissolved oxygen (DO) and non-filterable residue (NFR) content. The surface water samples were collected directly into the appropriate container, while the lower level water was collected using a Kahlsisco Model 135 water sampler. All containers were rinsed with sample water at least three times before filling.

The non-filterable residue samples were filtered through a preweighed, 1.5 um glass fibre filter in the field. The filter was sealed in tin foil, placed on dry ice and subsequently analyzed at the Environmental Protection Service laboratory in Whitehorse.

The dissolved oxygen samples were preserved in 200 ml glass DO bottles with a solution of manganese sulfate and alkali-iodide-oxide. The dissolved oxygen levels were done in duplicate and determined in the field within 24 hours using the modified Winkler method described in Environment Canada (1976). Percent saturation was calculated by the method of Strickland and Parsons (1968).

Water samples for nutrient and extractable metal analysis were collected at the freshwater station (Stokes Point Station 7). The sample for nutrients was collected in a two-litre polyethylene container and kept cool. The sample for extractable metals was collected in a 200 ml polyethylene container and preserved with concentrated nitric acid, as described in Environment Canada (1976). Both samples were shipped for analysis to the Environmental Protection Service laboratory in West Vancouver, British Columbia.

The preservation and analysis procedures for each water quality paramater are listed in Appendix I, Table 1.

3.2 Sediment

Sediment samples were collected with an Ekman dredge at the marine stations, while an aluminum scoop shovel was used at the freshwater lake station. Samples were placed into geochmical sample bags and then inside plastic Whirlpack™ bags. Samples were immediately frozen on dry ice and maintained at a cool temperature throughout transport.

The sediment samples were analyzed for extractable oils and grease, extractable metals and particle size at the Environmental Protection Service laboratory in West Vancouver. A description of the sediment sample preparation and analysis is shown in Appendix I, Table 2.

3.3 Bottom Fauna

Bottom fauna samples were obtained at the marine stations using an Ekman dredge (0.023 m^2). Five replicate grabs (0.115 m^2) were chosen to represent each station (P. Wainwright pers. comm.). These samples were sieved through a screen with a mesh opening size of 0.500 mm. The freshwater station was sampled using a Surber sampler (0.093 m^2) with a mesh opening size of 0.363 mm.

All samples were preserved in a 10% formalin solution. Samples were identified and enumerated by Dr. Charles J. Low, a consulting invertebrate biologist, in Nanaimo, British Columbia. Dr. Low conferred with Ed Bousefield of National Museum of Canada in Ottawa for identificaton of serveral organisms.

To numerically compare the invertebrate data, diversity indices were calculated using the following formula as described by Pielou (1975):

$$\text{Species Diversity } (H') = -\sum_{i=1}^{g} (P_i \log_{10} P_i)$$

where $P_i = n_i/N$

n_i = total number of individuals in the i^{th} genus in one sample

N = total number of individuals identified to genus and/or species taxonomic level in one sample

g = total number of genera in one sample

3.4 Tissue Samples

Tissue samples were obtained from local biota caught in a nylon mesh gill net set near King Point by a Department of Fisheries and Oceans field crew. A 100 g tissue sample was removed from the mid dorsal muscle area of a 30 cm long Arctic char (Salvelinus alpinus) and a 20 cm long fourhorn sculpin (Myoxocephalus quadricornus). Also, eight isopods, Saduria entomen (Mesidotea entomen), found feeding on the entrapped fish were collected. Since the isopods, which are normally detritus feeders, were engorged with fish tissue, the viscera were extracted and analyzed separately from the body.

The tissue samples were frozen and forwarded to the Environmental Protection Service laboratory in West Vancouver for metal analysis. The samples were analyzed using the Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Spectrometer as described for sediment analysis in Appendix I, Table 2. The preparation of tissue for this analysis involved freeze drying and grinding to obtain a homogeneous mixture. The sample was then decomposed of organic material using low temperature ashing and dilute acid as described in Department of Environment (1979).

4 RESULTS AND DISCUSSION

The results and discussion for the water quality, sediment and bottom fauna data have been subdivided into the following habitat categories: (i) nearshore marine, which includes Stokes Point Stations 3 to 8, excluding Station 7, and King Point Stations 4 to 8; (ii) lagoons, which comprise Stokes Point Stations 1 and 2 and King Point Stations 1 to 3; and (iii) freshwater lake, which includes Stokes Point Station 7 only.

4.1 Water Quality

The water chemistry data collected at Stokes Point and King Point are summarized in Appendix II, Tables 1a and 1b, respectively. The results of the water quality analysis for nutrients and extractable metals in the freshwater lake, Stokes Point Station 7, are presented in Appendix II, Table 2.

4.1.1 Nearshore Marine. Stokes Point and King Point nearshore stations were experiencing similar oceanographic conditions during the sampling period. All samples were within a salinity range of 29.0 to 35.3 $^{o}/_{oo}$ and a conductivity range of 26,400 to 31,500 umhos/cm. The salinity values approximate those found further offshore in the Arctic water mass by Wong et al (1975).

Mean surface water temperatures at Stokes Point and King Point were similar being 7.1 and 7.8 C, respectively. The mean difference between surface and near bottom levels were 0.9 C in both study areas. Dissolved oxygen levels were consistently high; in fact, all samples were supersaturated (102.1 to 108.9 %).

The salinity and temperature data showed no vertical column structuring and the variations between stations did not occur in any pattern. This indicates that localized mixing is occuring which is typical of open coastal waters. The data also suggests that the Mackenzie River influence was not present during the sampling period due to the consistently high salinity and low temperature measurements.

A regional variation was evident from the non-filterable residue measurements. Non-filterable residue or suspended solids is an indicator of the quantity of suspended inorganic and organic material, including plankton, in the water column. The Stokes Point stations had a mean suspended solids value of 12.9 mg/l (range 9 to 18 mg/l) while the King Point stations had a mean value of 5.3 mg/l (range 4 to 10 mg/l). This variation is attributed to differential suspended sediment loads produced from wave action and longshore drift and the variability in the standing stock of plankton. The similarity observed between suspended solids concentrations in the lagoons with the adjacent nearshore marine stations may suggest a dominant influence of plankton in the results, as it is unlikely that suspended sediment levels in the lagoons would be similar to the adjacent nearshore zone.

4.1.2 Lagoons. The lagoons near Stokes Point and King Point had higher water temperatures and lower salinity and conductivity values than the nearshore marine stations. The non-filterable residue concentrations corresponded closely to the adjacent nearshore marine stations as previously discussed. Both lagoons were well mixed as neither showed significant differences in temperature and salinity at the surface and near bottom levels.

The lagoons differed considerably in water chemistry parameters. The Stokes Point lagoon had mean surface salinity and conductivity readings of 19.9°/oo and 19,650 umhos/cm respectively, while the King Point lagoon had a considerably lower mean surface salinity of 6.6°/oo and a mean conductivity of 7,130 umhos/cm. The near bottom mean salinity values at the Stokes Point and King Point lagoons were 20.3 and 6.6 °/oo respectively. In the summer of 1975, Kendel et al (1975) recorded near bottom salinities of >40.0°/oo at the Stokes Point lagoon and 37.6°/oo at the King Point Lagoon.

The differing salinity readings of these two studies suggests that the lagoons exhibit considerable variations in water chemistry. Kendel et al recorded the presence of a halocline while the current study indicates thorough mixing of the water column.

4.1.3 **Freshwater Lake.** The water samples from the freshwater lake were analyzed for nutrients and extractable metals in addition to the standard water chemistry parameters. This data is presented in Appendix II, Table 2, along with a comparison to recommended levels for drinking water and healthy aquatic life. The discussion that follows is based upon the analysis of one water sample only, therefore, the interpretations made are dependent upon the reliability of this sample.

Turbidity exceeded the recommended level for drinking water by 2.5 Formazin Turbidity Units (an FTU is comparable to the conventional Jackson Turbidity Unit - APHA, AWWA, WPCF; 1981). This, combined with the non-filterable residue reading of 9 mg/l, suggests that the water has been slightly turbulent during the sampling period. This is consistent with McCart et al (1974), who reported that "tundra lakes tend to remain turbid throughout the open water season due to the constant turbulence resulting from strong winds".

Concentrations of nitrite and nitrate were below the detectable limits of 0.005 and 0.01 mg/l respectively while the concentrations of phosphorus (0.803 mg/l) and ammonia (0.032 mg/l) exceeded the recommended guidelines for aquatic life (0.02 for both). This nitrogen-phosphorus relationship is contrary to Wetzel's (1975) description of oligotrophic lakes which this particular lake was considered to be. Since oligotrophic lakes typically possess nitrogen mainly as nitrites and nitrates and relatively low levels of phosphorus, the results obtained seemed unusual and suggested possible degradation of the sample during storage and transport. Three other freshwater samples taken two days later and subjected to similar collection, transportation and analytical procedures showed the presence of nitrogen as nitrites and nitrates. Therefore the sample data from the lake is considered valid and suggests that at the time of sampling the nitrogen available to organisms as nitrites and nitrates was assimilated by organisms and was not present in the lake waters.

Concentrations of iron (0.758 mg/l) exceeded the recommended levels for drinking water (0.3 mg/l) and copper concentrations (0.007

mg/l) slightly exceeded the recommended levels for aquatic life (0.005 mg/l). The elevated iron concentration would contribute to the color reading of 15 color units.

The concentrations of aluminum (0.09 mg/l) and zinc (0.026 mg/l) were approaching the recommended levels for aquatic life (0.1 and 0.03 mg/l respectively). All of the other extractable metals analyzed were below the recommended levels obtained from the references.

4.2 Sediment

The results of the particle sizing of sediment samples collected at Stokes Point and King Point are shown in Appendix III, Tables 1a and 1b respectively. The results of the oils and grease, and extractable metal analysis, are presented in Appendix III, Tables 2a and 2b.

Sediment samples were not obtained from Stokes Point Station 4 and King Point Station 5 due to the gravelly substrate interferring with the operation of the Ekman dredge. As well, only two sediment samples were collected from King Point Station 4.

4.2.1 Nearshore Marine. The percent composition of particle size fractions varied considerably between stations indicating a heterogeneous or patchy distribution of sediment types. However, there was good correlation among the samples representing a particular station.

The substrate at Stokes Point ranged from gravel, at Stations 3 and 4, to fine sand at Stations 5, 6 and 8. At King Point, a mixture of gravels and silts were found at Stations 5 to 8 and coarse sand at Station 4. There was a considerable difference in the mean percent composition of particles less than 0.15 mm ranging from 15.1% at King Point Station 4 to 96.8% at Stokes Point Station 6. This is important because the extractable metal analysis is based upon this particle size fraction.

The term oils and grease is a collective group of natural oils, fats and hydrocarbons and the readings represent the concentra-

TABLE 2 MEAN CONCENTRATIONS OF SELECTED EXTRACTABLE METALS IN SEDIMENT SAMPLES FROM STOKES POINT AND KING POINT

LOCATION	NO. OF SAMPLES	EXTRACTABLE METALS (mg/kg) Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Stokes Point nearshore	12	<5	10.2	<0.3	19.3	9.4	20200	0.24	327	18	7.3	63.1
King Point nearshore	11	<5	15.7	<0.3	34.1	24.5	29800	0.26	459	31	9.6	107
Stokes Point lagoon	6	<5	14.7	<0.3	34.0	29.0	30900	0.32	377	30	12	114
King Point lagoon	9	<5	18.3	<0.3	41.4	32.5	34500	0.31	468	36	12	130

tion of those which are soluble in petroleum ether solvent. The oils and grease content at the Stokes Point nearshore stations had a mean concentration of 142 mg/kg (range <56 to 553 mg/kg), compared to a mean of 206 mg/kg (range 69 to 343 mg/kg) at the King Point nearshore stations. Results from a similar study done in MacKinley Bay (Fenton and Wainwright, 1982) using the hexane extraction method found concentrations up to 257 mg/kg and confirmed these to be normal background values through gas chromatrographic analysis.

Table 2 shows the mean concentrations of selected extractable metals. The results from each of the nearshore zones fall within the same order of magnitude. The Stokes Point nearshore zone was consistently lower than the King Point nearshore zone in levels of arsenic, chromium, copper, iron, manganese, nickel and zinc. Both nearshore zones had similar concentrations of silver, mercury, lead, and cadmium.

Figure 6 shows the level for arsenic, chromium, copper, iron, lead, mercury and zinc compared to data derived from Dome, Esso and Gulf (1982). Direct comparison to the Beaufort Sea data must be made with caution because the current study analysed the metal concentrations in the particle size fraction less than .15 mm while the Beaufort Sea studies analysed the whole sediment sample. Since there is an inverse relationship between grain size and extractable metal concentrations, our mean values should be invariably higher. However, since there are substrates with a predominance of particle sizes less than .15 mm (very fine sand, silt, and clay), the range of values should overlap and comparisons can be drawn.

The sediment metal concentrations presented in Figure 6 show no significant variation from the ranges reported at other Beaufort Sea locations except for mercury. The higher mercury concentrations expressed in the current study could be due to the above mentioned reasons.

4.2.2 Lagoons. The substrate in the two lagoons were similar in being fine textured and lacking gravel. The mean percent composition of particle size fractions less than 0.15 mm was 71.5% at Stokes Point and 68.6% at King Point.

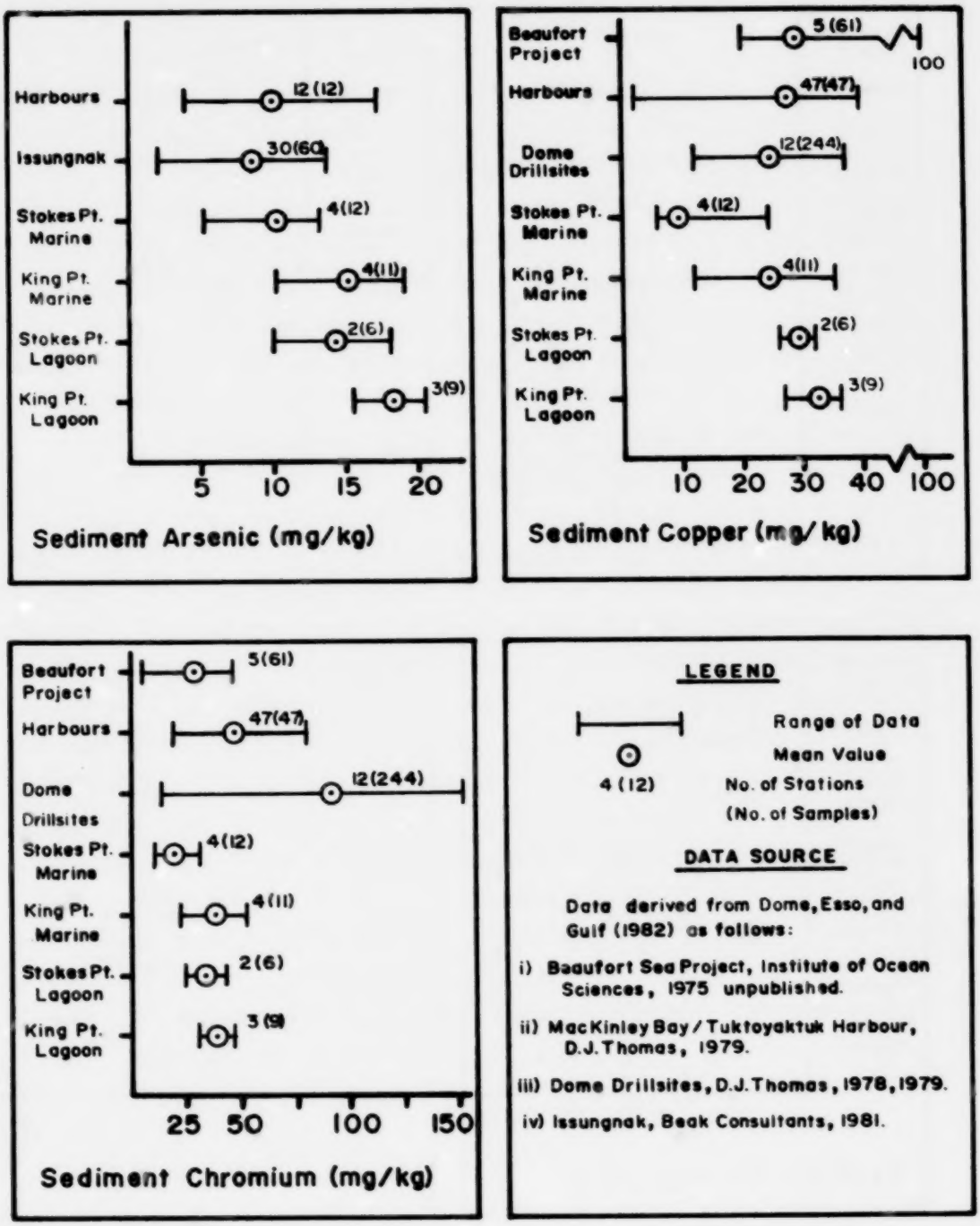

Figure 6 Comparison of selected extractable metal concentrations in sediment samples to other Beaufort Sea studies.

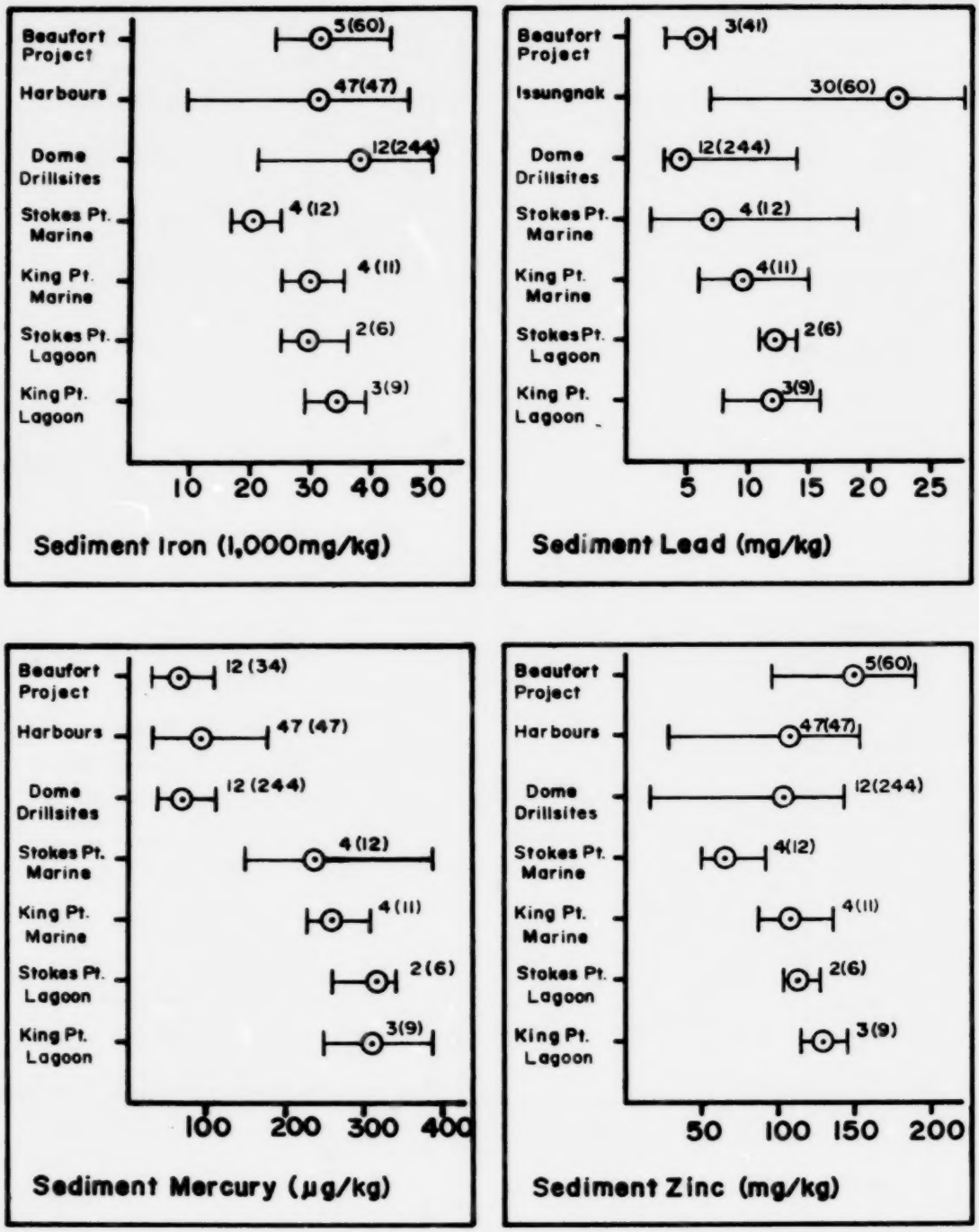

Figure 6 Comparison of selected extractable metal concentrations in sediment samples to other Beaufort Sea studies (continued).

Figure 7 shows the mean oils and grease content in sediment at all stations. The levels of oils and grease were generally higher in the lagoons (mean 726 mg/kg) compared with the nearshore stations (mean <177 mg/kg). In particular, Stokes Point Station 1 had the highest oils and grease mean content of 1,890 mg/kg (range 1,190 to 2,340 mg/kg). This significantly higher concentration indicates the presence of a localized source of oils and grease. However, the source cannot be identified due to the broad range of compounds measured by the analytical procedure.

The sediment metal analysis showed no significant difference between the two lagoons. The concentrations also compared closely to the results from the King Point nearshore stations but were consistently higher than the Stokes Point nearshores stations in all of the selected elements except arsenic (Table 2). The sediment mercury levels in the lagoons (mean 0.32 mg/kg) were slightly higher than the nearshore stations (mean 0.25 mg/kg). Considerable variation was observed in the sediment cadmium levels for Stokes Point Stations 1-2, 1-3 and 2-2 and King Point Stations 1-2 and 2-3 (Appendix III, Tables 2a and 2b). In replicate grab samples, sediment cadmium ranged from below detection limit of 0.3 mg/kg to 6.3 and even 43.1 mg/kg. This wide variation, combined with no correlation to other metal elements, suggests that these readings are unreasonable. The most probable explanation would be contamination of the sample after collection.

4.2.3 Freshwater Lake. The substrate in the lake was gravel with a very low proportion of particles less than 0.15 mm (mean 0.6%). This resulted in having insufficient quantity to complete the extractable mercury analysis on samples 7-1 and 7-2.

The results from the analysis for oils and grease and extractable metals generally fall within the ranges established at the nearshore marine stations.

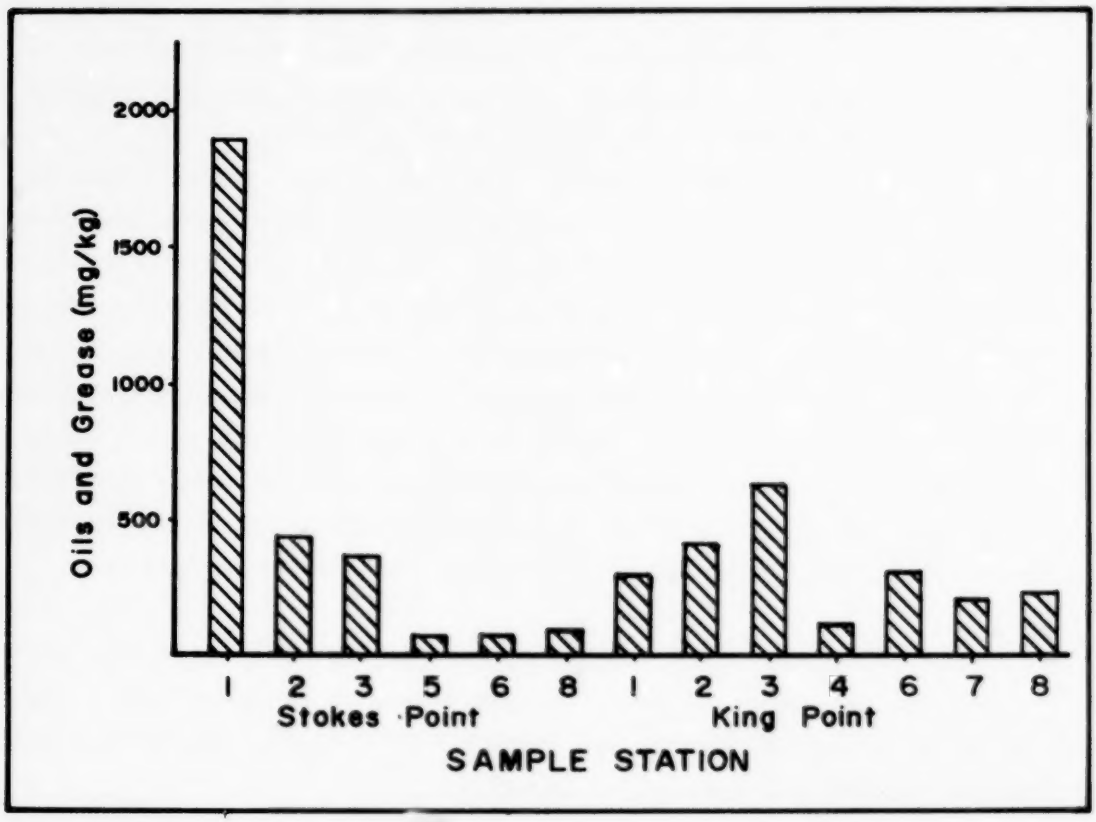

Figure 7 Mean concentrations of oils and grease in sediment samples from Stokes Point and King Point.

4.3 Bottom Fauna

A taxonomic list which outlines the benthic organisms collected is presented in Appendix IV, Table 1. Results of the analysis of bottom fauna samples are provided in Appendix IV, Tables 2a and 2b. Organisms for which the identification is tentative are shown in parentheses. A summary of the data collected in each grab sample is shown in Tables 3a and 3b.

A total of 51 bottom fauna samples were analyzed from 11 sampling stations. Samples were not obtained from Stokes Point Stations 3 and 4 and King Point Stations 4 and 5 due to the gravelly substrate. As well, only three samples were collected at Stokes Point Station 7 and King Point Station 6. The samples from King Point Station 8 were lost during transit.

4.3.1 Nearshore Marine. Fifteen samples (0.345 m^2 sample area) were collected from the three stations comprising the Stokes Point nearshore marine zone. Eight samples (0.184 m^2 sample area) were analyzed from the two stations representing the nearshore zone at King Point.

Twenty-three species were identified in the nearshore samples. The most abundant groups were the pelecypods (bivalves) and polychaetes representing 54% and 36%, respectively, of the total number of individuals collected. Kendel et al (1975) and Broad et al (1979) agree with this generalization, but they also recognize amphipods as a common inhabitant of the nearshore zone. The low number of amphipods recorded in our data is probably due to their ability to avoid entrapment in the Ekman dredge (Griffiths and Dillinger, 1981).

Eight species of polychaetes and five species of pelecypods were found in the nearshore zone. Species most frequently represented were Malacoceros fulginosus and Boreacola vadosa. Several species identified only in the Stokes Point nearshore samples had not been previously recognized in other Beaufort Sea literature (P. Wainwright, pers. comm.). These included an amphipod, Priscillina monocuspis (new

TABLE 3a SUMMARY OF THE BOTTOM FAUNA DATA COLLECTED AT STOKES POINT

STATION-SAMPLE	NUMBER OF SPECIES PRESENT	DIVERSITY (H')	DENSITY (no./m^2)
1-1	5	0.39	4520
1-2	3	0.41	2520
1-3	4	0.31	4040
1-4	5	0.39	3910
1-5	5	0.35	6170
2-1	7	0.40	5090
2-2	6	0.36	4610
2-3	7	0.42	3700
2-4	6	0.45	3740
2-5	5	0.35	4430
5-1	8	0.67	2000
5-2	8	0.66	1570
5-3	8	0.75	830
5-4	9	0.77	1220
5-5	9	0.76	1090
6-1	5	0.57	570
6-2	9	0.68	1000
6-3	12	0.86	1130
6-4	10	0.70	1390
6-5	7	0.59	700
7-1	2	0.30	90
7-2	2	0.0	130
7-3	0	0.0	0
8-1	3	0.30	130
8-2	8	0.83	350
8-3	10	0.96	740
8-4	5	0.68	260
8-5	7	0.71	430

TABLE 3b SUMMARY OF THE BOTTOM FAUNA DATA COLLECTED AT KING POINT

STATION-SAMPLE	NUMBER OF SPECIES PRESENT	DIVERSITY (H')	DENSITY (no./m^2)
1-1	4	0.41	1000
1-2	3	0.38	780
1-3	5	0.47	830
1-4	5	0.51	1040
1-5	3	0.29	740
2-1	5	0.45	870
2-2	3	0.41	220
2-3	4	0.35	1740
2-4	4	0.52	910
2-5	0	0.0	0
3-1	5	0.50	1650
3-2	5	0.51	2170
3-3	4	0.46	1350
3-4	3	0.35	1910
3-5	5	0.53	2650
6-1	3	0.38	260
6-2	1	0.0	90
6-3	2	0.22	220
7-1	2	0.30	170
7-2	0	0.0	0
7-3	3	0.0	300
7-4	0	0.0	0
7-5	2	0.0	90

species identified by Ed Bousefield, National Museum of Canada, Ottawa), two bivalves, Boreacola vadosa and Portlandia intermedia and a polychaete worm, Hobsonia florida.

The average number of species per station was 14 at Stokes Point and 4 at King Point. In a similar study, Kendel et al (1975) found 4 species per station at the 2.5 m depth and 25 species per station at the 12.5 m depth at Stokes Point, and 9 species per station at the 13 and 16 m depths at King Point. Wacasey (1975) stated that in water depths less than 15 m, diversities were normally less than 20 species per station and that diversities increased in zones greater than 15 m in depth. Wacasey also reported that invertebrate populations in the nearshore zone fluctuate considerably due to the inability of many species to tolerate the low salinities and unstable conditions.

Stokes Point and King Point nearshore samples had mean diversity index values of 0.70 (range 0.30 to 0.96) and 0.11 (range 0.0 to 0.38) respectively.

The population densities also differed greatly with a mean density of 890 individuals per meter squared (range 130 to 2,000/m^2) at Stokes Point and a mean density of 140 individuals/m^2 (range 0 to 300/m^2) at King Point. Kendel et al (1975) reported considerably lower densities at Stokes Point (439/m^2 at 12.5 depth) and similar densities at King Point (168/m^2 at 13.0 m depth).

In summary, the Stokes Point nearshore samples revealed consistently higher values in density, species diversity, and diversity index, as well as having the presence of several unique species. Further study is necessary in the Stokes Point nearshore zone to qualify whether the benthic community is different from other Beaufort Sea nearshore habitats. It should be noted that the comparatively lower values observed at King Point were partially attributed to the lower sample size and does not necessarily reflect a substantially lower bottom fauna population.

4.3.2 Lagoons

Ten bottom fauna samples were collected from the Stokes Point lagoon and 15 samples from the King Point lagoon. This represents a sampling area of 0.23 m^2 and 0.345 m^2, respectively, in the Stokes Point and King Point lagoons.

Seventeen species were found in the lagoon habitats. Of these, polychaetes, amphipods and pelecypods were the most represented taxonomic groups with 4, 2 and 4 species, respectively. However, in terms of abundance, the polychaetes and amphipods comprised 61% and 34% respectively of the total number of individuals sampled. Species frequently represented were Nephtys brachycephala, Laonice sp. and Byblis sp. The polychaete worm, Nephtys brachycephala, which was well represented in both lagoons, has not been recognized in other Beaufort Sea studies (P. Wainwright, pers. comm.). Species more characteristic of freshwater, such as the two bivalves Yoldia myalis and Macoma insconspicua and the mysid, Mysis occulata, were found in very low numbers at the King Point lagoon and absent in the Stokes Point lagoon samples. C. Low (pers. comm.) expressed some uncertainty with the identification of the latter three organisms. Although their presence would confirm the lower salinity observed in the King Point lagoon and may reflect a trend of decreasing salinity.

Eleven species were identified in the Stokes Point lagoon with an average of eight species per station. In the King Point lagoon, ten species were recorded averaging seven species per station. In comparison to the midsummer survey conducted by Kendel et al (1975), which recorded three and eight species per station respectively in the Stokes Point and King Point lagoons, the results of the present study show more diversity in the Stokes Point lagoon.

The two lagoons had similar diversity indices. The mean diversity index for samples from Stokes Point lagoon was 0.38 (range 0.31 to 0.45), and 0.41 (range 0.0 to 0.53) at King Point lagoon.

The lagoons differed considerably when comparing the population densities. Stokes Point lagoon had a mean density of 4,270 individuals/m^2 (range 2,520 to 6,170/m^2) and the King Point lagoon

had 1,190 individuals/m^2 (range 0 to 2,650/m^2). In a similar study, Kendel et al (1975) found significantly lower densities of 13/m^2 and 168/m^2 at Stokes Point and King Point lagoons, respectively. Griffiths et al (1975) reported a range of 650-4,161 individuals/m^2 in a summer survey at the Nunalak Lagoon, also on the Yukon Beaufort coast.

4.3.3 Freshwater Lake

The sampling of the freshwater lake consisted of three samples collected from one station (0.279 m^2 sampling area) at 0.2 m depth. The resulting data was sparse from which no firm conclusions can be drawn.

A total of five organisms were collected with a calculated mean density of 70 individuals/m^2 (range 0 to 130/m^2). In a survey of a similar lake located 5 km east of the sample site, de Graaf (1974, as cited in Gulf Canada, 1982), reported a mean density of 180 individuals/m^2 in six samples from depths of 1.0 and 1.25 m. However, in the 2 m and 3 m depths, de Graaf found substantial increases in densities to 1,000/m^2 and 4,870/m^2, respectively.

4.4 Tissue Analysis

The results of extractable metal analysis in tissue samples are presented in Appendix V, Table 1. The data is calculated on a dry weight basis.

In Figure 8, the results for cadmium, copper, chromium, mercury, lead and zinc are plotted against data derived from Dome, Esso, and Gulf (1982). The purpose of this is to determine how our single samples fit within the ranges established in more extensive studies. Caution is advised when drawing direct comparisons because our data is reported as extractable metals compared to total metals in the other studies.

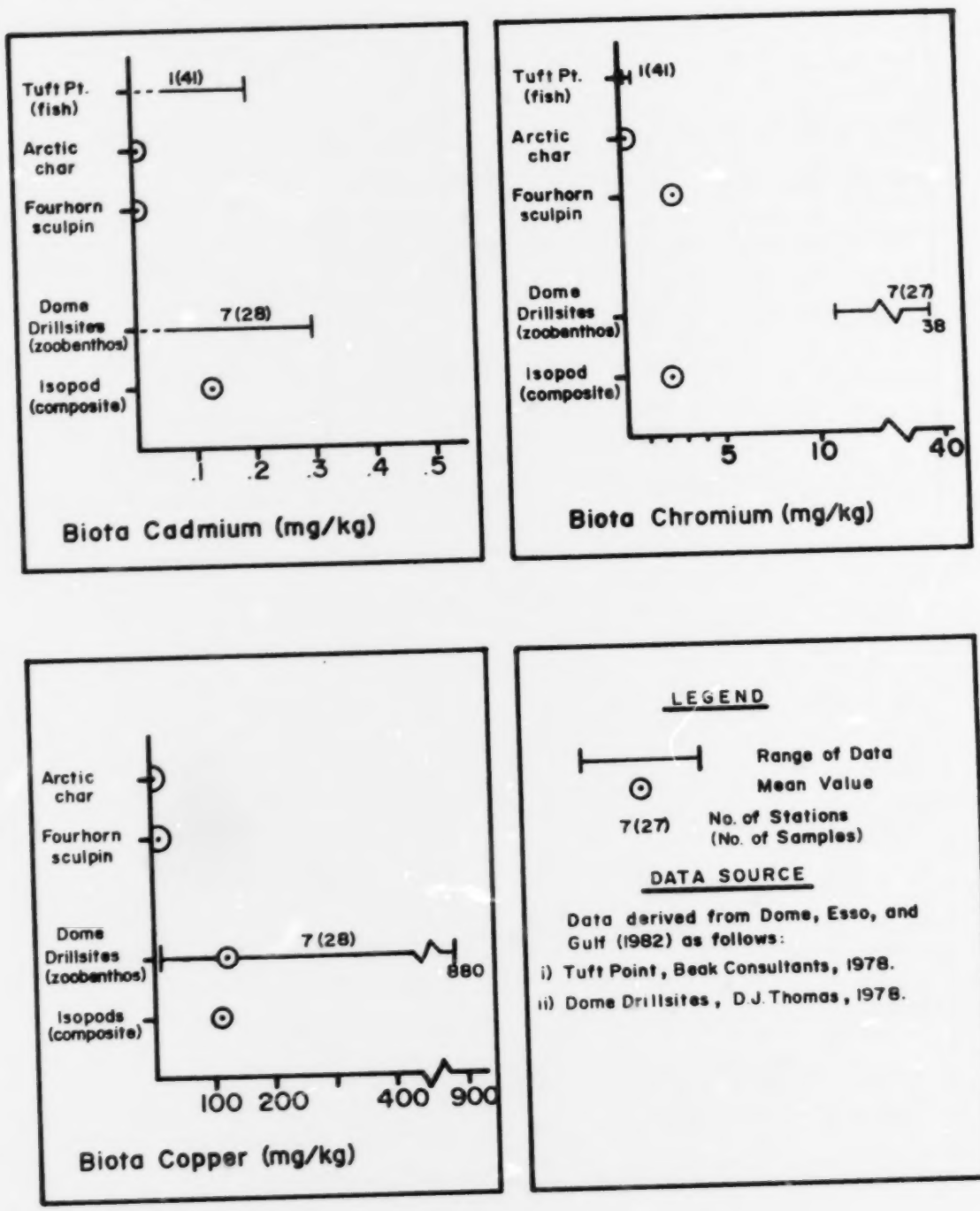

Figure 8 Comparison of selected extractable metal concentrations in tissue samples to other Beaufort Sea studies.

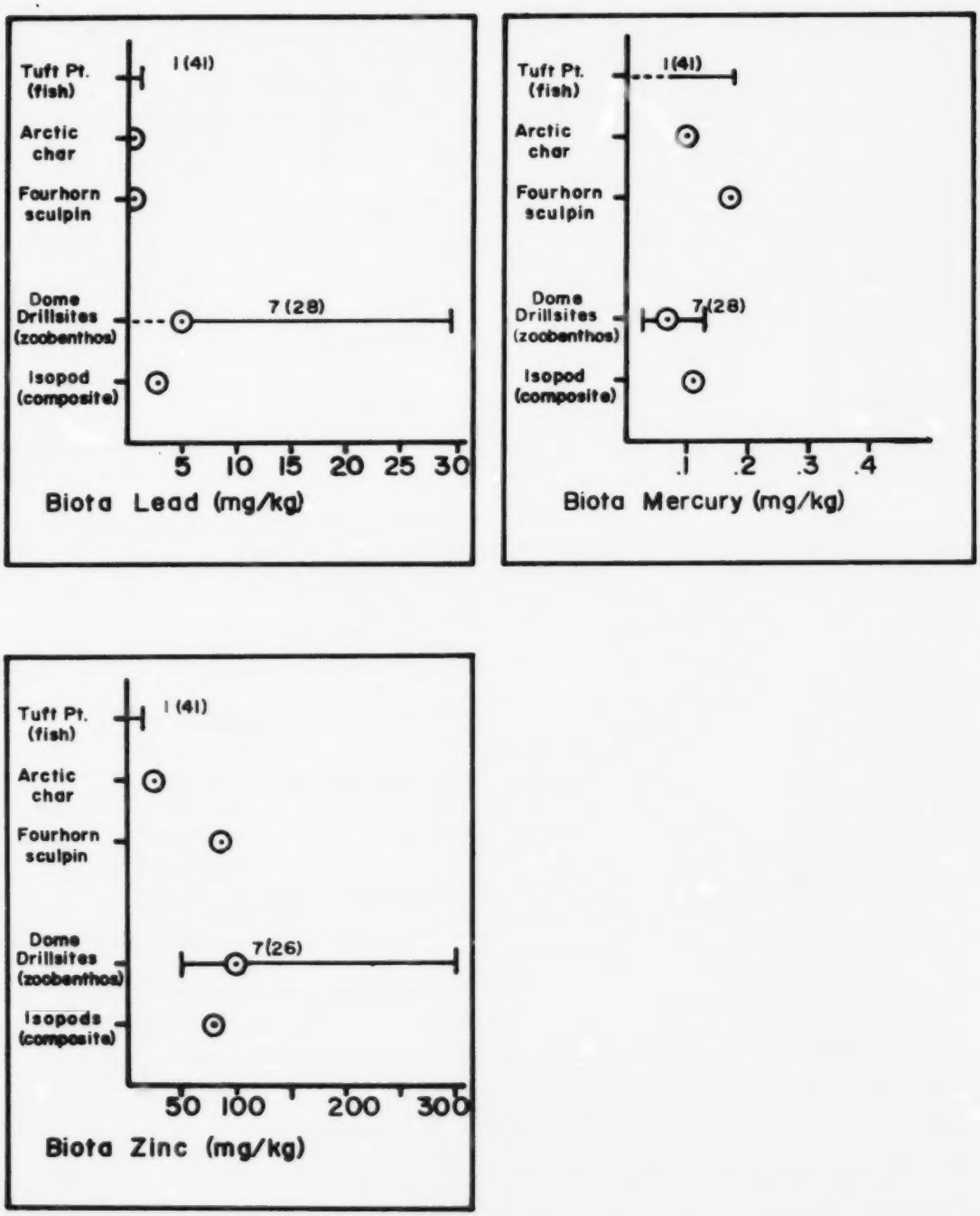

Figure 8 Comparison of selected extractable metal concentrations in tissue samples to other Beaufort Sea studies (continued).

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APPENDIX I

COLLECTION, PREPARATION AND ANALYSIS OF WATER AND SEDIMENT SAMPLES

APPENDIX I TABLE 1 MARINE WATER SAMPLE COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	DETECTION LIMIT	COLLECTION AND PREPARATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
MARINE WATER STATIONS				
Depth		In situ using a graduated handline.		
Temperature	±.1°C	In situ temperature reading.	Standard Centigrade Thermometer YSI Model 33 Conductivity Meter	
Dissolved Oxygen	1.00 mg/l	Duplicate samples collected in 300 ml glass BOD bottles. The BOD bottles were rinsed 3 times with sample before filling. Preserved with 2 ml manganese sulphate and 2 ml alkali-iodide-azide solution and shaken 15 times. A water seal was maintained and DO analysis was done within 7 days.	Iodometric Azide Modification Winkler Titration Method	048
Conductivity	0.2 umhos/cm	In situ measurement by lowering the receptor to the station depth.	YSI Model 33 Conductivity Meter	
Salinity	1.0°/oo	In situ measurement by lowering the receptor to the station depth.	YSI Model 33 Conductivity Meter	
Non-Filterable Residue (NFR)	1.00 mg/l	In the field, a 1 litre water sample was filtered through a pre-weighed glass fibre filter with a 1.5 um pore size. The filter and residue was returned to the Lab for drying and weighing.	Filtration, drying and weighing of residue on filter	104

APPENDIX I TABLE 2 FRESH WATER SAMPLE COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	DETECTION LIMIT	COLLECTION AND PREPARATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
FRESH WATER STATIONS				
Temperature		Same procedure used on marine stations.	Standard Centigrade Thermometer YSI Model 33 Conductivity Meter	
Dissolved Oxygen	1.0 mg/l	Same procedure used on marine stations.		048
pH		Small aliquots of sample were measured within 1 hour of collection. No preservative.	Potentiometric	080
Conductivity	0.2 umhos/cm	In situ measurement.	YSI Model 33 Conductivity Meter	044
Non-Filterable Residue (NFR)	1 mg/l	Same procedure used on marine stations.		104
Ammonia	0.0050 mg/l	Single samples collected in 2 litre linear polyethylene containers. The container was rinsed 3 times with sample before it was filled. No preservatives. Stored at 4°C.	Phenol Hypochlorite-Colorimetric-Automated	058
Colour	5 (colour units)	Same sample as NH_3.	Tristimulus	042
Turbidity	1.0 (FTU)	Same sample as NH_3.	Nephelometric Turbidity	130
Total Alkalinity	1.0 mg/l as $CaCO_3$	Same sample as NH_3.	Potentiometric Titration	006

APPENDIX I TABLE 2 FRESH WATER SAMPLE COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Total Phosphate T PO_4-P	0.0050 mg/l	Same sample as NH_3.	Acid-persulphate, Autoclave Digestion	086
Nitrite NO_2-N	0.010 mg/l	Same sample as NH_3.	Cadmium Copper Reduction Colorimetric Automated	072
Nitrate NO_3-N	0.010 mg/l	Same sample as NH_3.	Cadmium Copper Reduction Colorimetric Automated	072
Sulphate SO_4	1.00 mg/l	Same sample as NH_3.	Barium Chloranilate-UV Spectrophotometric	122
Chloride Cl	0.50 mg/l	Same sample as NH_3.	Thiocyanate-Combined Reagent-Colorimetric	024
Silicon Total Si	0.50 mg/l	Same sample as NH_3.	Ascorbic Acid Reduction - Colorimetric	118
Extractable Metals	mg/l	Single samples collected in 200 ml linear polyethylene bottles. The bottle was rinsed 3 times with sample before filling. Preserved to a pH <1.5 using 2.0 ml concentrated HNO_3.	Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Spectrometer (OES)	210 592
Al	0.050			
As	0.075			
Ba	0.0015			
Be	0.0010			
Ca	0.050			
Cd	0.0040			
Co	0.0075			
Cr	0.0075			
Cu	0.0050			

APPENDIX I TABLE 2 FRESH WATER SAMPLE COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Extractable Metals (con't)	mg/l			
Fe	0.0050			
Mg	0.10			
Mn	0.0010			
Mo	0.015			
Na	0.050			
Ni	0.040			
Pb	0.040			
Sb	0.040			
Se	0.075			
Sn	0.10			
Sr	0.0020			
Tl	0.0040			
V	0.020			
Zn	0.0050			
As	0.00050	Same sample as metals.	Hydride Generation-ICAP.	350
Cd	0.0010	Same sample as metals.	Graphite Furnace-ICAP.	330
Cu	0.0010	Same sample as metals.		
Pb	0.0010	Same sample as metals.		
Ag	0.030	Same sample as metals.	Flame Atomic Absorption Spectrophotometry	340

APPENDIX I TABLE 2 FRESH WATER SAMPLE COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
K	0.010 mg/l	Same sample as metals.	Flame Atomic Emission Spectrophotometry	340
Hg	0.00020 mg/l	Same sample as metals.	Flame Atomic Absorption	370
Total Hardness	0.030 mg/l as $CaCO_3$	Same sample as metals.	The sum of the ICAP results for Mg x 4.116 and Ca x 2.497 reported as mg/l $CaCO_3$	

1 As described in Environment Canada (1976).

2 As described in Department of Environment (1979).

APPENDIX I TABLE 3 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
All Parameters	Samples were collected and placed in geochemical sampling bags within Whirlpack™ bags. Samples were frozen and kept cool through transportation. No preservatives were required.		
Extractable Metals Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, Pb, Sl, Sn, Sr, Ti, V, Zn	A sediment sample was dried in a low temperature oven then screened through a 100 mesh (0.15 mm) sieve. The material passing through the sieve was then leached with HCl and HNO_3.	Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Sepctrometer (OES)	320
Cd, Cu	Same sample as metals.	Atomic Absorption Graphite Furnace	330
K, Ag	Same sample as metals.	Flame Atomic Absorption Spectrophotometry	340
As	Same sample as metals.	Hydride Generation - ICAP	350
Hg	The sample was solved as described for metals and was completely oxidized by digestion with sulfuric acid peroxide.	Flameless Atomic Absorption	370

APPENDIX I TABLE 3 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
Particle Sizing	A dry, pre-weighed sample was passed through selves of the following mesh size: 9.5 mm, 2.38 mm, 1.19 mm, .297 mm .149 mm, and .074 mm.	Dry sieve	078
Oils and grease	A sample of air dried sediment was placed in the Soxhlet apparatus with petroleum ether solvent. The solvent dissovles the oils and grease which is then evaporated and the residue weighed.	Petroleum ether Soxhlet Extraction	725

APPENDIX II

WATER QUALITY DATA

APPENDIX II TABLE 1a WATER CHEMISTRY DATA COLLECTED AT STOKES POINT, AUGUST 4-5, 1982.

STOKES POINT STATION	DESCRIPTION	DATE	LOCAL TIME	SAMPLE DEPTH (m)	TEMPERATURE (°C)	OXYGEN (mg/l)	O_2 SATURATION (%)	CONDUCTIVITY (100umhos/cm)	SALINITY (°/oo)	NON-FILTERABLE RESIDUE (mg/l)
1-1	lagoon	82-08-05	1508	0	7.9	10.6	101.1	204	20.5	13
1-2				2.5	7.9	10.6	101.8	209	21.6	9
2-1	lagoon	82-08-05	1349	0	8.5	10.4	100.0	189	19.3	8
2-2				3.0	8.5	10.4	99.8	188	19.0	9
3-1	sea	82-08-04	2133	0	7.0	10.4	104.0	280	30.8	18
3-2				4.5	6.7	10.4	103.5	280	31.2	13
4-1	sea	82-08-04	1930	0	7.2	10.3	103.5	279	30.5	15
4-2				4.5	6.1	10.5	102.1	265	29.5	15
5-1	sea	82-08-04	1828	0	7.3	10.5	108.2	315	34.5	9
5-2				4.5	6.0	10.6	107.0	312	35.3	10
6-1	sea	82-08-04	1721	0	7.5	10.5	104.9	270	29.0	14
6-2				4.5	6.0	10.6	102.8	268	29.7	9
7	lake	82-08-04	1300	0	8.0	11.0	91.9	0.4	0	9
8-1	sea	82-08-04	2140	0	6.5	10.4	104.0	290	32.5	--
8-2				5.0	6.2	10.5	104.0	286	32.0	--

APPENDIX II TABLE 1b WATER CHEMISTRY DATA COLLECTED AT KING POINT, AUGUST 6-7, 1982.

KING POINT STATION	DESCRIPTION	DATE	LOCAL TIME	SAMPLE DEPTH (m)	TEMPERATURE (°C)	OXYGEN (mg/l)	O_2 SATURATION (%)	CONDUCTIVITY (100umhos/cm)	SALINITY (°/oo)	NON-FILTERABLE RESIDUE (mg/l)
1-1	lagoon	82-08-07	1100	0	10.0	10.4	95.3	71	6.5	5
1-2				2.8	10.0	10.4	95.3	71	6.5	5
2-1	lagoon	82-08-07	1517	0	10.4	10.6	98.0	68	6.2	4
2-2				3.3	10.1	10.5	96.2	69	6.2	5
3-1	lagoon	82-08-07	1255	0	10.0	10.5	96.3	75	7.0	5
3-2				2.5	9.8	10.5	96.2	78	7.0	12
4-1	sea	82-08-06	1307	0	7.0	10.5	104.2	271	29.6	4
4-2				4.5	6.4	10.6	103.5	269	29.3	6
5-1	sea	82-08-06	1839	0	8.1	10.5	106.9	281	30.0	6
5-2				4.5	7.1	10.6	105.5	272	29.8	5
6-1	sea	82-08-06	1744	0	8.2	10.3	104.7	278	29.6	4
6-2				4.5	7.0	10.7	106.2	271	29.5	4
7-1	sea	82-08-06	1551	0	7.9	10.5	108.6	305	32.9	5
7-2				4.5	7.0	10.5	106.6	301	33.1	10
8-1	sea	82-08-06	1445	0	7.6	10.5	108.9	308	34.1	5
8-2				4.5	7.0	10.6	108.4	308	34.1	4

APPENDIX II TABLE 2 WATER QUALITY ANALYSES FOR THE FRESHWATER LAKE, STOKES POINT STATION 7, WITH A COMPARISON TO RECOMMENDED LEVELS FOR DRINKING WATER AND AQUATIC LIFE (numbers in brackets indicate the source of reference).

WATER CHEMISTRY	% D.O. SATURATION (%)	pH	CONDUCTIVITY (umhos/cm)	COLOUR (colour units)	TURBIDITY (FTU)	NON-FILTERABLE RESIDUE
Stokes Point Station 7	91.9	7.6	40	15	7.5 (FTU)	9
Levels for drinking water	near 100(1)	5.0-9.6(1)	--	25-75(1)	5(JTU)(1)	80(7)
Levels for aquatic life	$\geq$54(2)	6.5-9.0(3)	150-500(4)	--	--	--

NUTRIENT (mg/l)	TOTAL ALKALINITY	TOTAL HARDNESS	TOTAL PO_4-P	NITRITE NO_2-N	NITRATE NO_3-N	AMMONIA NH_3-N	SULFATE SO_4	CHLORIDE Cl
Stokes Point Station 7	12.0	13.1	.083	<.005	<.01	.032	4.3	3.6
Levels for drinking water	30-500(7)	100-350(1)	.2(7)	1.0(1)	10.0(1)	.5(1)	150-250(1)	250(1)
Levels for aquatic life	$\geq$100(4)	--	.02(2)	--	--	.02(2)	--	--

APPENDIX II TABLE 2 WATER QUALITY ANALYSIS FOR THE FRESHWATER LAKE, STOKES POINT STATION 7, WITH A COMPARISON TO RECOMMENDED LEVELS FOR DRINKING WATER AND AQUATIC LIFE (numbers in brackets indicate the source of reference) (continued).

METALS (mg/l)	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg
Stokes Point Station 7	<.03	.09	.003	.016	<.001	3.6	<.0005	<.005	<.005	.007	.758	<.0002	.42	1.0
Levels for drinking water	.05(1)	n/a(5)	.01-.05(1)	1.0(1)	--	75-200(5)	.01(1)	--	.05(1)	1.0(1)	.3(1)	.002(1)	--	50.0(1)
Levels for aquatic life	.0001(6)	.1(2)	.05(6)	5.0(5)	--	--	.0002(6)	--	.04(6)	.005(2)	1.0(3)	.0002(6)	--	--

METALS (mg/l)	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
Stokes Point Station 7	.029	<.005	2.1	<.02	<.05	.001	<.05	<.05	.4	<.01	.013	<.002	<.01	.026
Levels for drinking water	.05(1)	--	20(1)	.25(6)	--	.05(1)	--	.01(1)	--	n/a(5)	--	--	--	5.0(1)
Levels for aquatic life	1.0(5)	--	--	.025(6)	--	.005(6)	--	.01(1)	--	--	--	--	--	.03(2)

APPENDIX II TABLE 2 WATER QUALITY CRITERIA

REFERENCES

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(4) Environment Canada, Pollution Sampling Handbook. Pacific Region Laboratory Services, Fisheries Operations and Environmental Protection Service, West Vancouver, B.C. (1976).

(5) California State Water Resources Control Board, Water Quality Criteria. Publication No. 3-A Second Edition by McKee and Wolf (1963).

(6) Inland Waters Directorate, Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Environment Canada, Ottawa (1979, 1980).

(7) Hart, B.T., A Compilation of Australian Water Quality Criteria. Research Project No. 71/36. Department of the Environment and Conservation, Australian Water Resources Council, Australian Government Publishing Service (1974).

APPENDIX III

SEDIMENT DATA

APPENDIX III TABLE 1a PERCENT COMPOSITION OF VARIOUS PARTICLE SIZE CLASSES IN THE SEDIMENT SAMPLES COLLECTED FROM STOKES POINT

SAMPLE NUMBER	PARTICLE SIZE					
	<.075 mm	.075-.15 mm	.15-.30 mm	.30-1.18 mm	1.18-2.36 mm	>2.36 mm
1-1	51.5	14.6	11.2	22.2	0.4	--
1-2	52.5	10.3	9.1	27.9	0.1	0.1
1-3	48.0	17.8	8.9	25.2	0.1	--
2-1	62.0	19.2	8.6	10.2	--	--
2-2	56.5	17.7	11.4	14.3	0.1	--
2-3	63.1	16.0	7.0	11.8	0.1	2.0
3-1	2.5	32.7	20.0	9.6	3.6	31.6
3-2	42.1	19.7	10.5	3.6	1.9	22.2
3-3	11.3	23.1	13.4	8.6	4.1	39.6
5-1	2.5	84.3	10.7	2.5	0.1	--
5-2	1.9	56.3	41.6	0.2	0.1	--
5-3	0.6	22.2	76.4	0.6	0.2	0.1
6-1	4.7	91.3	3.6	0.2	0.1	0.1
6-2	5.5	92.0	2.3	0.1	--	--
6-3	4.6	92.1	3.2	0.1	--	--
7-1	0.4	0.5	16.5	35.4	8.0	39.3
7-2	0.2	0.2	4.8	42.2	12.6	40.1
7-3	0.1	0.4	11.8	43.2	6.4	38.0
8-1	17.1	51.0	16.7	13.9	0.7	0.7
8-2	6.9	75.0	10.9	6.7	0.4	0.2
8-3	5.7	75.4	12.7	5.9	0.2	--

APPENDIX III TABLE 1b PERCENT COMPOSITION OF VARIOUS PARTICLE SIZE CLASSES IN THE SEDIMENT SAMPLES COLLECTED FROM KING POINT

SAMPLE NUMBER	PARTICLE SIZE					
	<.075 mm	.075-.15 mm	.15-.30 mm	.30-1.18 mm	1.18-2.36 mm	>2.36 mm
1-1	20.1	19.0	44.3	16.5	0.1	0
1-2	51.0	10.2	18.8	19.8	0.2	0
1-3	23.5	22.0	28.4	24.8	1.3	0
2-1	47.0	14.0	18.5	20.3	0.3	0
2-2	53.9	9.8	10.9	25.0	0.3	0.2
2-3	99.4	0.4	0.1	0.1	0	0
3-1	83.0	8.3	4.2	4.4	0	0
3-2	87.3	7.7	0.1	4.9	0.1	0
3-3	71.5	8.5	4.5	15.5	0	0
4-1	5.1	5.3	14.1	42.0	12.5	21.1
4-2	15.3	4.9	8.9	46.5	12.8	11.6
6-1	7.4	21.2	32.5	14.8	5.9	18.2
6-2	43.4	14.0	14.0	8.6	3.0	17.0
6-3	41.3	8.5	6.2	4.3	1.8	37.9
7-1	21.4	10.5	15.4	22.7	2.3	27.7
7-2	30.0	7.7	9.6	16.9	3.9	31.9
7-3	30.3	14.4	15.1	26.4	1.5	12.4
8-1	14.0	7.6	4.5	10.8	3.9	59.1
8-2	25.3	41.9	8.6	12.9	3.2	8.1
8-3	25.8	10.4	4.3	7.8	1.7	50.0

APPENDIX III TABLE 2a CONCENTRATIONS OF OILS AND GREASE AND EXTRACTABLE METALS IN THE SEDIMENT SAMPLES COLLECTED AT STOKES POINT

SAMPLE NUMBER	Oils & Grease (mg/kg)	EXTRACTABLE METALS (mg/kg) Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
1-1	2140	<5	26500	18.2	95.8	228	.8	15400	<.3	14.6	41.4	31.5	34000	.34	7370
1-2	2340	<5	21300	10	66.9	194	.7	15400	15.6*	9.6	34.5	29.6	35700	.34	5420
1-3	1190	<5	22900	14	69.8	202	.7	15200	43.1*	8.3	36.4	30.8	35400	.32	5630
2-1	425	<5	18500	16.8	53.9	184	.6	23500	<.3	9	30.9	28.8	28200	.33	4160
2-2	421	<5	18200	14.4	51.5	178	.6	25400	6.7*	10.4	30.4	26.6	25800	.32	4030
2-3	430	<5	18100	14.5	48.3	176	.6	24700	<.3	11.7	30.5	26.6	26300	.26	3980
3-1	108	<5	9700	10.5	13.3	111	.2	39400	<.3	7.8	17	7.3	17800	.21	2250
3-2	553	<5	13000	5	50	180	.46	30300	<.2	9.1	24.1	23.4	21000	.39	2970
3-3	416	<5	17100	12.8	46.8	211	.5	31200	<.3	11.6	28.8	24.5	22800	.32	4100
5-1	<55	<5	9220	11	23.7	323	.2	39900	<.3	10.7	19.1	6.9	25000	.22	1800
5-2	<57	<5	9190	13	15.4	207	.3	38400	<.3	9.6	18.5	6.8	23300	.16	1850
5-3	62	<5	10800	8	21.5	345	.3	41300	<.3	10.4	21	7.3	25000	.19	2350
6-1	<56	<5	10100	10.2	17.5	126	.3	41400	<.3	8.5	18	6.3	17800	.25	2410
6-2	<56	<5	9400	9.91	16.8	102	.2	41400	<.3	8.7	16.7	6	17800	.15	2070
6-3	70	<5	9490	9.6	14.7	125	.2	43000	<.3	6.1	16.8	6	17700	.27	2140
7-1	120	<5	10500	15	13.4	250	.2	19100	<.3	15.2	27	9.3	41900	--	1820
7-2	60	<5	8760	9	13.1	227	.3	11400	<.3	4.2	20.5	12.6	23700	--	1510
7-3	59	<5	8930	10	19.6	148	.2	13700	<.3	10.5	17	6.9	28800	.28	1640
8-1	77	<5	9890	11.5	17.5	130	.2	39900	<.3	5	16.9	6.4	19000	.22	2240
8-2	87	<5	9750	10.5	17.4	109	.3	40400	<.3	5.4	16.2	5.7	17000	.21	2270
8-3	105	<5	10700	10.9	17.2	148	.4	45600	<.3	5.2	18.3	5.7	18500	.23	2590

* Results suspected of contamination after collection.

APPENDIX III TABLE 2a CONCENTRATIONS OF OILS AND GREASE AND EXTRACTABLE METALS IN THE SEDIMENT SAMPLES COLLECTED AT STOKES POINT (continued)

SAMPLE NUMBER	Extractable Metals (mg/kg)												
	Mg	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Sr	Ti	V	Zn
1-1	10200	369	<.8	7440	35	1350	14	2920	<2	84.4	207	79	127
1-2	9780	373	<.8	6790	29	1520	12	6670	<2	79.9	168	66	119
1-3	10000	399	<.8	6650	29	1410	11	6180	<2	82.3	182	69	124
2-1	9060	387	<.8	3660	27	1030	11	6930	<2	87.7	161	57	107
2-2	8790	358	<.8	2630	29	986	13	5950	<2	89.4	166	56	102
2-3	9050	374	<.8	2700	29	999	11	5880	<2	85.7	168	56	102
3-1	6150	262	<.8	690	16	1060	13	4290	<2	105	171	30	54
3-2	7510	370	1.8	2660	26	843	19	2980	<.8	94.8	143	42.5	84.1
3-3	8070	399	<.8	2620	28	942	10	3330	<2	99.5	206	53	91.7
5-1	7700	383	<.8	770	20	1670	6	4740	<2	110	384	36	68.4
5-2	7500	354	<.8	710	18	1510	6	4610	<2	104	315	35	65.6
5-3	8000	378	<.8	990	19	1690	6	4380	<2	118	430	40	70.4
6-1	6690	305	<.8	1180	17	1120	6	4340	<2	111	203	31	53.3
6-2	6860	297	<.8	920	17	1130	5	4640	<2	110	189	29	54.7
6-3	6840	318	<.8	890	16	1140	4	3440	<2	113	192	29	53.5
7-1	5230	520	<.8	370	24	2010	9	3480	<2	74.3	409	72	92
7-2	4200	431	1.1	450	26	1370	18	5020	1	49.3	104	33	83.6
7-3	4350	402	<.8	280	17	1590	9	3730	<2	52.4	227	39	69.3
8-1	6420	287	<.8	1100	15	1100	4	4740	<2	108	168	31	55.7
8-2	5990	254	<.8	840	14	992	4	5930	<2	108	135	29	51.4
8-3	6960	313	<.8	820	14	1180	4	4370	<2	119	208	33	54.6

APPENDIX III TABLE 2b CONCENTRATIONS OF OILS AND GREASE AND EXTRACTABLE METALS IN THE SEDIMENT SAMPLES COLLECTED AT KING POINT

SAMPLE NUMBER	Oils & Grease (mg/kg)	Extractable Metals (mg/kg) Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
1-1	232	<5.	28400	19.7	59.8	286.	.9	8410	<.3	14.4	45.6	34.2	37500	.32	6670
1-2	278	<5.	28400	20.2	73.2	294.	1.	8210	7.5*	14.8	45.6	36.1	38500	.26	6380
1-3	330	<5.	28600	19.9	66.1	286.	.9	8120	<.3	13.5	45.3	34.3	38500	.3	6770
2-1	498	<5.	25700	18.6	52.1	282.	.9	9280	<.3	16.8	41.8	34.6	35700	.34	5740
2-2	434	<5.	26700	18.3	49.5	289.	.8	9680	<.3	9.2	42.7	34.3	36200	.33	5960
2-3	263	<5.	27200	19.8	69.	294.	.9	9540	6.3*	13.8	43.4	35.5	36700	.39	6170
3-1	714	<5.	21200	15.8	53.6	240.	.7	9530	<.3	9.9	34.9	27.1	28900	.34	4640
3-2	637	<5.	22400	16.1	42.7	249.	.7	9600	<.3	16.8	37.1	29.2	28900	.29	5110
3-3	555	<5.	22000	15.9	43.	250.	.7	9230	<.3	10.3	35.9	26.9	29200	.25	5040
4-1	69	<5.	17800	16.1	37.1	199.	.6	11100	<.3	10.6	28.3	19.8	28000	.25	3890
4-2	145	<5.	19000	16.6	41.6	186.	.6	12100	<.3	12.8	30.5	22.8	28700	.28	4290
6-1	141	<5.	13100	18.3	21.1	295.	.4	11200	<.3	11.5	22.4	11.9	27100	.26	2550
6-2	285	<5.	15800	11.	23.4	189.	.5	11300	<.3	14.6	26.9	17.	25300	.26	3270
6-3	465	<5.	16100	10.1	26.5	184.	.5	10900	<.3	9.5	27.3	17.7	25800	.26	3200
7-1	177	<5.	24200	19.3	46.9	463.	.7	8410	<.3	10.7	39.9	28.5	34500	.26	5480
7-2	163	<5.	25200	19.5	52.8	437.	.8	7940	<.3	15.6	42.4	30.8	35300	.26	5810
7-3	257	<5.	29000	17.5	56.	468.	.8	7490	<.3	18.2	47.4	35.5	35500	.27	6810
8-1	343	<5.	24500	13.6	48.7	286.	.7	11300	<.3	16.8	39.1	30.1	31200	.23	5390
8-2	209	<5.	21600	14.1	46.7	282.	.6	11300	<.3	15.8	35.5	27.6	28600	.26	4870
8-3	114	<5.	20500	16.6	56.3	225.	.6	6980	<.3	9.2	35.3	27.4	27500	.31	4900

* Results suspected of contamination after collection.

APPENDIX III TABLE 2b CONCENTRATIONS OF OILS AND GREASE AND EXTRACTABLE METALS IN THE SEDIMENT SAMPLES COLLECTED AT KING POINT (continued)

SAMPLE NUMBER	EXTRACTABLE METALS (mg/kg)												
	Mg	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Sr	Ti	V	Zn
1-1	8150	473.	<.8	2610	38.	1260.	13.	4300.	3.	66.8	139.	88.	138.
1-2	8340	478.	<.8	2550	40.	1260.	16.	4820.	<2.	67.6	140.	88.	143.
1-3	8090	469.	<.8	2560	38.	1300.	12.	3620.	<2.	67.2	139.	87.	140.
2-1	8070	503.	<.8	1910	41.	1190.	15.	5980.	<2.	64.4	141.	81.	136.
2-2	8240	515.	<.8	2350	35.	1180.	10.	5160.	3.	67.2	145.	83.	134.
2-3	8360	520.	<.8	2820	38.	1200.	13.	5120.	<2.	67.4	145.	85.	136.
3-1	7320	417.	<.8	2000	31.	1120.	9.	3530.	<2.	57.9	139.	67.	115.
3-2	7370	422.	<.8	1830	37.	1120.	13.	3860.	<2.	58.5	152.	71.	117.
3-3	7260	418.	<.8	1600	30.	1130.	8.	4940	<2.	57.5	144.	69.	115.
4-1	5880	498.	<.8	2130	26.	1290.	7.	4940	<2.	61.6	100.	55.	96.6
4-2	6340	530.	<.8	2050	30.	1290.	8.	4910	<2.	64.	109.	57.	107.
6-1	5090	531.	<.8	1020	22.	1680.	7.	6020	<2.	55.	130.	44.	85.8
6-2	6200	481.	<.8	1600	28.	1100.	9.	6700	<2.	47.9	153.	48.	86.
6-3	6470	474.	<.8	1540	26.	986.	6.	5890	<2.	48.4	145.	48.	88.6
7-1	7020	466.	<.8	2760	33.	1300.	9.	6040	2.	63.6	161.	82.	121.
7-2	7230	482.	<.8	2780	37.	1270.	12.	5990	3.	61.5	159.	85.	127.
7-3	7970	492.	<.8	3810	41.	1120.	15.	5430	<2.	65.	168.	95.	135.
8-1	7670	401.	<.8	2310	36.	997.	11.	4480	<2.	63.6	149.	74.	106.
8-2	7130	361.	<.8	2090	33.	944.	13.	5930	<2.	61.7	148.	70.	108.
8-3	6460	328.	<.8	1880	28.	945.	9.	4150	<2.	51.5	164.	73.	117.

APPENDIX IV

BOTTOM FAUNA DATA

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT AND KING POINT (the numbers correspond to the organism referenced in Appendix IV, Table 2)

	Phylum Class Order Family *Genus species*
1.	Nemertea
	Anopla
	Paleonemertea
2.	*Carinoma mutabilis*
	Nemathelmia
3.	Nematoda
	Annelida
	Chaetopoda
4.	Polychaeta
	Suborder: Nereidiformia
	Phyllodocidae
5.	*Eteone longa*
6.	*Eteone* sp.
	Nephthydidae
7.	*Nephtys brachycephala*
	Aricidae
8.	*Scoloplus* sp.
	Suborder: Spioniformia
9.	Spionidae
10.	*Laonice* sp.
11.	*Malacoceros fulginosus*
	Suborder: Terebelliformia
	Cirratulidae
12.	*Cirratulus* sp.
13.	Terebellidae
	Terebellides stroemi

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT AND KING POINT (the numbers correspond to the organism referenced in Appendix IV, Table 2)(continued)

	Ampharetidae
14.	*Hobsonia florida*
	Suborder: Capitelliformia
	Capitellidae
15.	*Capitella capitata*
16.	Oligochaeta
17.	Enchytraeidae
	Gephyrea
	Priapulida
18.	*Priapulus* sp.
	Arthropoda
	Crustacea
19.	Subclass: Ostracada
	Subclass: Copepoda
	Calanoida
	Centropagidae
20.	*Limnocalanus macrurus*
21.	Subclass: Cirripedia
	Subclass: Malacostraca
	Mysidacea
	Mysidae
22.	*Mysis occulata*
	Cumacea
	Diastylidae
23.	*Diastylis alaskensis*
24.	*Diastylis* sp.
	Isopoda
	Idoteidae
25.	*Saduria entomen* (*Mesidotea entomen*)
	Amphipoda
	Suborder: Gammaridea
	Ampeliscidae
26.	*Byblis* sp.

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT AND KING POINT (The numbers correspond to the organism referenced in Appendix IV, Table 2)(continued)

Oedocerotidae
27. *Paroediceros lynceus**

Pontoporeidae
28. *Priscillina monocuspis**

Gammaridae
29. *Gammarus lacustris*
30. *Gamaracanthus loricatus*

Insecta
Plecoptera
Perlodidae
31. *Kogotus* sp.

Tricoptera
Limnephilidae
32. *Clostoeca* sp.

Mollusca
Pelecypoda
Prionodesmacea
Nuculidae
33. *Yoldia myalis*

Nuculanidae
34. *Portlandia artica*
35. *P. intermedia*

Teleodesmacea
Tellinidae
36. *Macoma balthica*
37. *M. moesta*
38. *M. inconspicua*

Saxicavidae
39. *Cyrtodaria kurriana*

Montacutidae
40. *Boreacola vadosa*

* Taxonomic identification by E. Bousefield, National Museum of Canada, Ottawa.

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT AND KING POINT (the numbers correspond to the organism referenced in Appendix IV, Table 2)(continued)

Gastrapoda
Subclass: Opisthobranchia
Tectibranchia
Scaphandridae
41. Cylichna alba

APPENDIX IV TABLE 2a BOTTOM FAUNA COLLECTED AT STOKES POINT

ORGANISM \ STOKES POINT	STATION 1					STATION 2					STATION 5				
	1-1	1-2	1-3	1-4	1-5	2-1	2-2	2-3	2-4	2-5	5-1	5-2	5-3.	5-4	5-5
1. Nemertea								1							
2. (Carinoma mutabilis)												1	2	2	1
6. Eteone sp.	1	2		2											
7. Nephtys brachycephala	64	30	57	56	76	34	38	45	32	31					
8. Scoloplos sp.											3		2	1	5
10. Leonice sp.	33	24	35	28	63	1	1	3	6	3		2	1	2	
11. Malacoceros fuliginosus											7	11	2	5	3
12. Cirratulus sp.											5	2			
13. Terebellides stroemi					1										
14. Hobsonia florida											3		1	3	
16. Oligochaeta (eggs/cysts)						1	3	2		2					
17. Enchytraeidae						13	10	1	1	6					
18. (Priapulus sp.)	4	2		3	1					1					
20. Limnocalanus macrurus						2	1	2	1						
21. Cirripedia															1
24. Diastylis sp.															1
25 Saduria entomon					1	1									
26. Byblis sp.						63	52	30	44	59		1			
34. Portlandia arctica						2	1		2		2	1	2	2	1
35. P. intermedia											1	4	3	1	3
36. Macoma balthica	2		1	1											
37. M. moesta															1
39. Cyrtodaria kurriana											2			1	
40. Boreacola vadosa											23	14	6	11	9
41. Cylichna alba								1							
Total organisms (T)	104	58	93	90	142	117	106	85	86	102	46	36	19	28	25
Total at genera level (N)	104	58	93	90	142	103	93	81	85	94	46	36	19	28	24
Diversity index (H')	0.39	0.41	0.31	0.39	0.35	0.40	0.36	0.42	0.45	0.35	0.67	0.66	0.75	0.77	0.76

APPENDIX IV TABLE 2a BOTTOM FAUNA COLLECTED AT STOKES POINT (continued)

ORGANISM	STOKES POINT	STATION 6					STATION 7			STATION 8				
		6-1	6-2	6-3	6-4	6-5	7-1	7-2	7-3	8-1	8-2	8-3	8-4	8-5
2. (Carinoma mutabilis)				1							1		1	
3. Nematoda								1						
6. Eteone sp.			1											
8. Scoloplos sp.		1										1		1
10. Leonice sp.		1		3	3	2					1	1		
11. Melacoceros fuliginosus				1	3						1	2	1	3
12. Cirratulus sp.		2		1							1	3		1
14. Hobsonia florida												1		
15. Capitella capitata			1	1	1									
18. (Priapulus sp.)				1										
19. Ostracoda			1											
21. Cirripedia										1		1		
24. Diastylis sp.				1						1				
26. Bybis sp.			3	3	1	1								
27. Paroediceros lynceus			2		1								1	1
28. Priscillina monocuspis			1	1	1	1								
29. Gammarus lacustris							1							
31. Kogotus sp.							1							
32. Clostoeca sp.								2						
34. Portlandia arctica			1		4						2	1	2	2
35. P. intermedia		2	1	1	1	1						2		1
37. Macoma moesta										1	1	2		
39. Cyrtodaria kurriana				1	1	2						2	1	1
40. Boreacola vadosa		7	12	11	16	9					1	1		
Total organisms (T)		13	23	26	32	16	2	3	0	3	8	17	6	10
Total at genera level (N)		13	22	26	32	16	2	2	0	2	8	16	6	10
Diversity index (H')		0.57	0.68	0.86	0.70	0.59	0.30	0.0	0.0	0.30	0.83	0.96	0.68	0.71

APPENDIX IV TABLE 2b BOTTOM FAUNA COLLECTED AT KING POINT

ORGANISM	KING POINT STATION 1 1-1	1-2	1-3	1-4	1-5	STATION 2 2-1	2-2	2-3	2-4	2-5
4. Polychaeta unidentified	1		1							
7. Nephtys brachycephala	6	8	5	13	3	8	3	8	7	
9. Spionidae						1				
10. Laonice sp.	3	1	2			1		2		
20. Limnocalanus macrurus					1			1	4	
22. (Mysis occulata)				2						
25. Saduria entomon				1						
26. Bybiis sp.	13	9	10	7	13	9	1	29	9	
30. Gammaracanthus (loricatus)				1						
33. Yoldia (myalis)			1							
38. Macoma (inconspicua)						1			1	
39. Cyrtodaria kurriana							1			
Total organisms (T)	23	18	19	24	17	20	5	40	21	0
Total at genera level (N)	22	18	18	24	17	19	5	40	21	0
Diversity index (H')	0.41	0.38	0.47	0.51	0.29	0.45	0.41	0.35	0.52	0.0

APPENDIX IV TABLE 2b BOTTOM FAUNA COLLECTED AT KING POINT (continued)

ORGANISM	KING POINT	STATION 3					STATION 6			STATION 7				
		3-1	3-2	3-3	3-4	3-5	6-1	6-2	6-3	7-1	7-2	7-3	7-4	7-5
2. (Carinoma mutabilis)			1											
4. Polychaeta unidentified		3												
5. Eteone longa														
7. Nephtys brachycephala		7	8	4	8	5			1			1		1
9. Sphonidae														
10. Laonice sp.		14	12	9	5	19	4	2	4	2		4		
17. Enchytraeidae														
20. Limnocalanus macrurus			2			6	1					2		1
23. Diastylis (alaskensis)										2				
25. Saduria entomen							1							
26. Byblis sp.		13	27	17	31	30								
33. Yoldia (myalis)		1												
38. Macoma (inconspicua)				1		1								
Total organisms (T)		38	50	31	44	61	6	2	5	4	0	7	0	2
Total at genera level (N)		35	50	31	44	61	6	2	5	4	0	1	0	1
Diversity Index (H')		0.50	0.51	0.46	0.35	0.53	0.38	0.0	0.22	0.30	0.0	0.0	0.0	0.0

APPENDIX V

TISSUE ANALYSIS

APPENDIX V TABLE 1 CONCENTRATIONS OF EXTRACTABLE METALS IN THE TISSUE SAMPLES COLLECTED AT KING POINT (dry weight)

SPECIMEN	EXTRACTABLE METALS (mg/kg) Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg
Arctic Char	<2.	3.	1.35	<.05	<.05	1110.	<.05	<.2	.4	5.	11.7	.1	12700.	798.
Isopods (composite)	372.	7.	38.2	23.9	<.05	87800.	1.28	3.2	2.4	111.	944.	.11	7800.	5220.
Isopods (digestive tract)	3320.	17.	9.9	111.	.19	12400.	.8	26.8	9.4	79.5	8280.	<.01	12300.	4650.
Fourhorn Sculpin	34.	4.	4.5	6.76	<.05	45100.	.07	<.3	2.6	12.6	195.	.17	12900.	1370.

SPECIMEN	EXTRACTABLE METALS (mg/kg) Mn	Mo	Na	Ni	P	Pb	Sb	Si	Sn	Sr	Ti	V	Zn
Arctic Char	.92	<.2	1490	<1.	7660	<.05	<2.	<5.	<.5	3.06	<.1	<.5	24.5
Isopods (composite)	204.	.9	17600	7.8	6710	2.6	<2.	750.	<.5	1320.	1.2	.9	77.2
Isopods (digestive tract)	190.	.9	16800	20.	4190	5.	<3.	114.	<.5	163.	10.4	13.6	111.
Fourhorn Sculpin	7.7	<.3	9010	2.	27000	<.05	<3.	79.	<.5	173.	<.1	<.5	88.3

POOR

QUALITY

ORIGINAL